THE IMPACT OF HEARING LOSS

ON CHILDHOOD DEVELOPMENT AND FAMILY CONSTELLATION

2019 RESEARCH FORUM

TUESDAY, JULY 2, 2019
9:00 A.M. – 12:30 P.M.
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AG BELL GLOBAL
LISTENING AND SPOKEN LANGUAGE
SYMPOSIUM

CONTENTS

Childhood Development after Cochlear Implantation: Results from a Prospective Longitudinal Investigation

Laurie S. Eisenberg, Ph.D., on behalf of the CDaCI Investigative Team

The Tina and Rick Caruso Department of Otolaryngology-Head and Neck Surgery, University of Southern California

Childhood Development after Cochlear Implantation (CDaCI) is a prospective national investigation that tracks developmental outcomes in a group of children receiving cochlear implants in early childhood. Taking a whole-child approach, the children are assessed with regard to spoken language, speech production, speech recognition, psychosocial functioning, and cost utility/quality of life. Despite wide variability, results indicate that early access to sound via cochlear implants is advantageous for spoken communication and other indices of development.

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PEARLS: An Intervention to Improve Parent-Child Interactions and Communication

Ivette Cejas, Ph.D., and Alexandra L. Quittner, Ph.D.

University of Miami

Parents play a critical role in facilitating language development in children with hearing loss. Specifically, the quality of parent-child interactions, including maternal sensitivity (MS) and facilitative language techniques (FLTs) have been shown to positively affect children's spoken language. This presentation will report on a parent-focused intervention to improve parental sensitivity and communication (Parent-Child Early Approaches to Raising Language Skills – PEARLS). The effectiveness and feasibility of this intervention will also be discussed.

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Supporting the Hearing Device Use of Infants and Toddlers Enrolled in Early Intervention

Sophie E. Ambrose, Ph.D., Margo Appenzeller, Ph.D., and Sarah Al-Salim, Au.D.

Center for Childhood Deafness, Language, and Learning; Boys Town National Research Hospital

This presentation brings together data from several studies to provide a picture of the challenges faced by professionals and parents in supporting the hearing device use of infants and toddlers. The presentation will highlight tools that professionals can utilize to better understand how often children are wearing their hearing devices and what supports families need to optimize device use. Additionally, evidence-based strategies for supporting children's hearing device use will be shared.

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Family Environment Contributions to Children's Neurocognitive Development

Rachael Frush Holt, Ph.D.

Department of Speech and Hearing Science, Ohio State University

One important influence on development in children who are deaf or hard of hearing is the family environment. We are evaluating children who use cochlear implants and hearing aids in their homes to understand how families influence spoken language and executive function development. Whereas family environments are not fundamentally different from those of children with typical hearing, variability is seen across families and even small changes can have more important influences on developmental outcomes.

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MODERATOR | **Howard W. Francis, MD, MBA, FACS**

Dr. Francis is professor and chief of the division of Head and Neck Surgery & Communication Sciences in the Department of Surgery at Duke University Medical Center, Durham, NC, where he is also co-leading the enhancement of regional pediatric hearing intervention and cochlear implant services at Duke. Dr. Francis' clinical interests include the management of conditions of the ear, skull base, and associated nervous system. His research interests include the determination of best practices of acoustic neuroma treatment, the examination of functional outcomes of cochlear implantation in young children and older adults, and the study of best practices in surgical education. Prior to his appointment at Duke University, Dr. Francis spent 19 years on the faculty at Johns Hopkins during which he served as Residency Program Director, Director of the Johns Hopkins Listening Center and Vice Director of the Department of Otolaryngology-Head and Neck Surgery. He is a member of the Board of Directors of the Alexander Graham Bell Association for the Deaf and Hard of Hearing.

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Childhood Development after Cochlear Implantation: Results from a Prospective Longitudinal Investigation

Laurie S. Eisenberg, Ph.D., on behalf of the CDaCI Investigative Team
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ABSTRACT

The Childhood Development after Cochlear Implantation (CDaCI) Study is a longitudinal, multisite investigation that tracks spoken communication and other developmental outcomes in children with cochlear implants (CI) as well as in children with typical hearing (TH). The assessment protocol covers the broad developmental domains of spoken language/speech production, speech recognition, psychosocial functioning, and quality of life/cost utility. Enrollment and CI surgery occurred during the first two years of the study (2002-2004) across six large CI centers, enrolling a total of 188 children with severe to profound hearing loss (mean age = 2.2 years) and 97 children with TH (mean age = 2.3 years). The hypothesis being tested is that early access to sound via cochlear implants will have positive effects on children's spoken communication with other far-reaching developmental consequences. Despite impressive rates of growth post-CI on language measures, results indicate broad variability with approximately half of the CI group performing on par with peers who have TH. Factors that contribute to performance outcomes include age receiving CI, pre-CI residual hearing, parent-child interactions (specifically, maternal sensitivity), socioeconomic status, and early language input via listening and spoken language, among others. A cost-utility analysis, derived from estimates of medical costs, educational savings, and quality-adjusted life years, indicates that pediatric CIs are one of the most cost-effective medical procedures in the United States.

INTRODUCTION

In 1980, Dr. William F. House performed the first cochlear implant (CI) surgery on a child born with profound hearing loss (Eisenberg & House, 1982); the device was a single-channel CI. This event was the catalyst for conducting pediatric clinical trials, first with single- and then multichannel implants, until the first multichannel CI (Nucleus by Cochlear Corporation) was approved by the U.S. Food and Drug Administration (FDA) in 1990 (Staller, 1991). Trials with other multichannel CI systems (Advanced Bionics and MedEL) followed and subsequently achieved FDA approval.

Those early FDA pediatric clinical trials were sponsored by the CI manufacturers to demonstrate efficacy with the specific goal of attaining marketing approval. Around the same time, the first independent investigations on children with CIs were being undertaken by researchers at the Central Institute for the Deaf (CID) (e.g., Geers & Moog, 1994) and Indiana University School of Medicine (e.g., Miyamoto et al., 1989), with support from the National Institutes of Health. The study objectives were to determine whether CIs (single- and multichannel) were of equal or greater benefit to children with profound sensorineural hearing loss compared to other non-surgical alternatives (hearing aids and vibrotactile devices). Because the early results from those first investigations exceeded expectations, particularly for multichannel devices, the Indiana group increased the benchmark for comparison to children with severe hearing loss who used hearing aids (Eisenberg et al., 2004; Holt et al., 2005). With steady improvements in outcomes as a result of earlier CI surgery and advanced signal processing, the field of pediatric CIs evolved to such an extent that children with typical hearing (TH) became the next comparison group with the initiation of the *Childhood Development after Cochlear Implantation* (CDaCI) Study. In this proceedings paper, the CDaCI Study design and participants are briefly described. Notable findings are highlighted, with emphasis on listening and spoken language communication.

THE CDaCI STUDY

Using a 'whole child' approach, the CDaCI Study evaluates the effects of early access to sound with CIs through longitudinal and domain-driven assessments in a prospective and multisite investigation. Children with CIs are compared to peers with TH in areas of spoken language, speech production, auditory performance, psychosocial functioning, and quality of life/cost utility. An important goal of the CDaCI Study is to identify the sources of variance that characterize potential predictors both affecting and affected by language development across developmental domains. As shown in Figure 1, the pediatric CI participants received implants at six U.S. clinical centers:

Johns Hopkins University, University of North Carolina, University of Miami, University of Michigan, University of Texas at Dallas, and the University of Southern California. A Data Coordinating Center at Johns Hopkins University and a Psychosocial Measurement Center at Nicklaus Children's Research Institute oversee data collection and analysis. The comparison group of children with TH are recruited and assessed at the River School in Washington, D.C., and the Callier Center of the University of Texas at Dallas. It is noteworthy that the CDaCI Investigative Team represents a multidisciplinary endeavor, successfully uniting practitioners with clinical researchers.

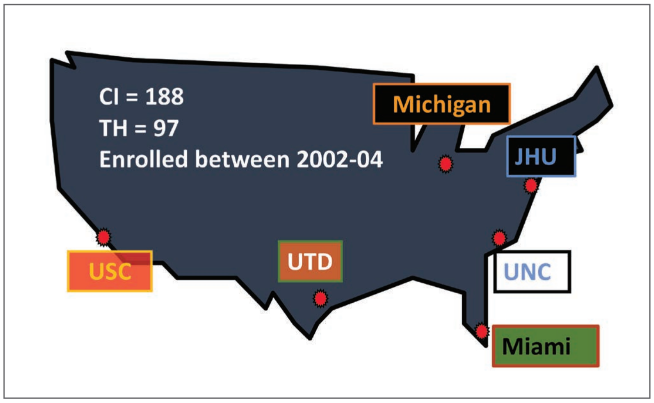


FIGURE 1. The six clinical sites that enrolled CI participants into the CDaCI Study and conduct test protocols.

PARTICIPANTS

Study enrollment and CI surgery occurred between 2002 and 2004 across the six participating CI centers. Extensive inclusion and exclusion criteria are beyond the scope of this paper, but can be found in Fink et al., 2007. During these first two years of the study, children under 5 years of age were consecutively evaluated for a CI at their participating centers. The total number screened was 425. Of those, 268 children met criteria but 80 families chose not to participate, resulting in a total of 188 children enrolled (Fink et al., 2007). The mean four-frequency unaided pure-tone average for the better hearing ear for the CI group was 105.1 dB HL (Niparko et al., 2010). It should be noted that bilateral CIs had not yet become standard clinical practice when the CDaCI Study commenced. During the course of the study many of the children in the CI cohort received a second implant. Children with TH totaled 97, being recruited at the Callier Center of the University of Texas at Dallas and the River School in Washington, D.C.

The mean age at enrollment of the children with severe to profound hearing loss was 2.2 years; the mean age of the group of children with TH at enrollment was 2.3 years. Extensive baseline information of the CI and TH cohorts will be found in Fink et al. (2007), with partial demographics reported here in Table 1. As shown in Table 2, the CI cohort closely resembles the racial/ethnic composition of the United States according to the 2000 census (Belzner & Seal, 2009; Wang et al., 2012).

Despite equivalency between CI and TH groups for the most relevant demographics, the socio-economic status (SES) of parents in the CDaCI Study differs significantly, with the parents of the children with TH having higher SES than parents of the CI group. Due to this discrepancy, many of the CDaCI tests utilize measures collected by the National Institute of Child Health and Human Development Early Childcare Database (National Institute of Child Health and Development, Early Child Care Research Network, 1999, 2000). The inclusion of these data as well as reliance on standardized measures provide additional performance comparisons between the CI cohort and their peers with TH.

TABLE 1. CDaCI demographics for the CI and TH groups.

Child	**CI (*N*=188)**	**TH (*N*=97)**
Age (years)	2.2 (1.2)	2.3 (1.1)
Gender		
Male	90 (48%)	37 (38%)
Female	98 (52%)	60 (62%)
Ethnicity		
Non-Hispanic	145 (77%)	86 (89%)
Hispanic	37 (20%)	9 (9%)

Parent	**CI (*N*=188)**	**TH (*N*=97)**
Age 30-39	96 (51%)	59 (61%)
College Graduate	92 (49%)*	81 (84%)*
Income >$100,000	31 (16%)*	49 (51%)*

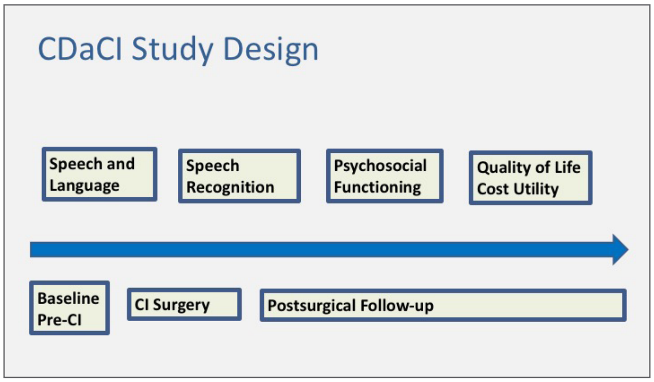
*p > .05
Adapted from Fink et al. (2007).

TABLE 2. Race/ethnicity comparison between the CI cohort in the CDaCI Study and the 2000 census.

Race/Ethnicity	**CDaCI %**	**2000 Census %***
White	64	63
Black	9	15
Hispanic	20	17
Asian	6	4
Other	1	1
Unknown/Refused	6	–

*Reported in Belzner & Seal (2009)
Adapted from Wang et al. (2012) and Belzner & Seal (2009).

FIGURE 2. Block diagram of the CDaCI Study research design.



STUDY DESIGN

A simplified diagram of the research design is shown in Figure 2. The figure displays the four primary domains of investigation that encompass pre-CI evaluation, surgery, and post-CI follow-up. Readers are referred to Fink et al. (2007) for a more detailed description of the study design. Post-CI assessments occurred in 6-month intervals for the first 3 years and then yearly until 13 years post-CI follow-up testing. Comprehensive test batteries provide the longitudinal datasets that are amenable to growth curve estimation. Multivariable-adjusted analyses model the effects of CIs throughout childhood and adolescence. The study tests the hypothesis that early access to sound via CIs will have positive effects on children's listening and spoken language communication with other far-reaching developmental consequences.

RESULTS

Listening and Spoken Language Communication

Findings from select studies are highlighted with emphasis on spoken language development, accompanied by supporting data from speech recognition, speech intelligibility, and literacy. Results from several prominent papers and a presentation are briefly described here. At 3 years post-CI, Niparko and colleagues (2010) sorted the study participants into the following categories based on age at CI activation (CI group) and age at enrollment (TH group): < 18 months, 18-36 months, and > 36 months. Raw scores from the Reynell Developmental Language Scales (RDLS; Reynell & Gruber, 1990) were analyzed at baseline and for the first 3 years with the CI. Results indicated large variability for the CI group. Notably, the group receiving CIs earlier yielded significantly steeper slopes in language growth than the two groups receiving CIs later; however, gaps between the CI and TH groups were evident for the earliest group and even greater for the two later age groups. In addition to age-at-CI activation, other baseline factors shown to predict language growth were pre-CI residual hearing, parent-child interactions (maternal sensitivity), and socioeconomic status.

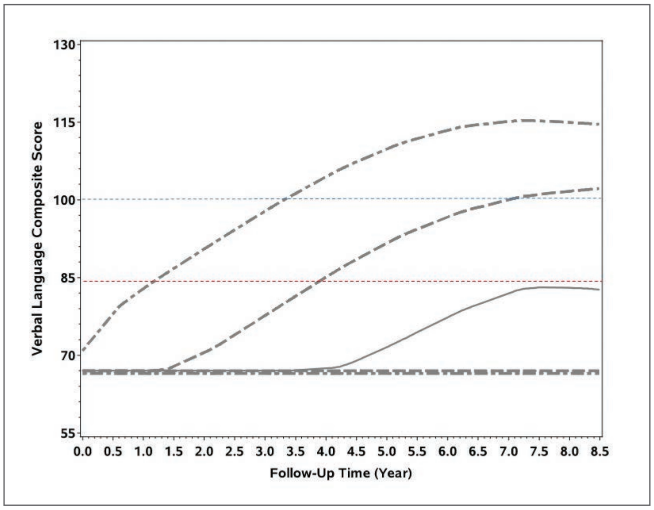
Data were next analyzed by Tobey and colleagues (2013) only for the CI group at 4-to-6 years post-CI. By this point in the study, the children had transitioned from the RDLS to the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk, 1999), using the core composite standard scores for analysis. The CI group was sorted into six quintiles based on age they received a CI (i.e., earliest quintile = .6 to 1.25 months; latest quintile = 40.5 to 59 months). The earliest age-at-implant group clearly demonstrated the highest scores with means falling above the benchmark of 85 (one standard deviation of the standardized mean), signifying age-appropriate language.

In a related analysis conducted at 4-to-6 years post-CI, Eisenberg and colleagues (2016) investigated associations between CASL standard scores and sentence recognition scores from the Hearing In Noise Test for Children (HINT-C; Nilsson et al., 1996). Sentence recognition was administered in quiet and in noise (+10, +5, and 0 dB signal-to-noise ratio [SNR]). The percent-correct scores were derived from the number of whole sentences correctly repeated by the child. Strong positive associations were found between language and sentence recognition scores when the sentence test was administered in quiet and at +10, but essentially negligible at 0 dB SNR. These results corroborated the interdependence of linguistic skills and sentence recognition (particularly vocabulary and syntactic knowledge). Notably, those children eligible to be assessed on sentence recognition at 4-to-6 years post-CI represented the top 50th percent of the cohort, having progressed through a hierarchical battery of speech recognition tests for which sentence recognition in noise is the most difficult level to reach (Eisenberg et al., 2006).

By 8 years post-CI, Wang and colleagues (2015) distributed the CI cohort into quintiles (10th, 25th, 50th, 75th, and 90th) based on RDLS and CASL scores across the 8 years of data collection. As can be seen in Figure 3, the distribution shows the trajectories of the top three quintiles through 8 years post-CI (90th, 75th, and 50th). Based on standard scores of 85 and higher, approximately 50% of the cohort were found to be on par with their peers who had TH in spoken language by 8 years post-CI.

In the most recent language analysis, Geers and colleagues (2017) compared the effects of communication mode (sign vs. no sign) as reported by parents at pre-CI and during the first 3 years post-CI on later spoken language, speech recognition, speech intelligibility, and literacy. Language and literacy were measured at two time points—early and late elementary school. A subsample of the CI participants were placed into one of the following three groups based on reported communication modality: 1) no sign pre- or post-CI, 2) short-term sign (pre-CI and up to 1 year post-CI), or 3) long-term sign (pre-CI and/or 12 months post-CI and at 36 months post-CI). The groups did not differ statistically on pre-CI baseline demographics,

FIGURE 3. Language trajectories through 8 years post-CI for the top 50% of the CDaCI cohort: 90% (top curve), 75% (middle curve) and 50% (bottom curve). Standard scores of 100 (blue line) and 85 (red line) are indicated (Wang et al., 2015).



language, or auditory performance. Post-CI, the analyses revealed that the no sign group demonstrated significant advantages by late elementary school compared to the two sign groups on the communication skills assessed.

It should be noted that a small proportion of children with CIs who participate in the CDaCI Study are reliant on sign language. This finding was reported in a study by Barnard and colleagues (2015) who examined baseline variables that might differentiate children achieving open-set speech recognition by 5 years post-CI from those children unable to achieve this milestone. Most of the children who were unable to achieve open-set speech recognition were communicating via sign language. Although the study doesn't indicate whether one skill predicted the other, the investigators identified baseline factors significantly associated with limited auditory performance post-CI. They included older age at hearing aid fitting, less functional hearing with hearing aids prior to CI surgery, lower baseline maternal sensitivity, and complicated perinatal history (i.e., prematurity, NICU), among others.

Psychosocial Effects on Language

Many publications that have resulted from the CDaCI Study represent the broad area of psychosocial functioning. Here we focus on one study that investigated parental factors and the ways in which they contribute to language development in the children with CIs. Quittner and colleagues (2013) investigated the effects of parent-child interactions during structured and unstructured play activities on spoken language during the first 4 years post-CI. The interactions were video recorded and coded for maternal sensitivity, cognitive stimulation, and linguistic stimulation based on rating scales. The scales for maternal sensitivity and cognitive stimulation were developed by the National Institute of Child Health and Development Early Child Care Study (National Institute of Child Health and Development, Early Child Care Research Network, 1999, 2000). The linguistic stimulation scale was developed by the investigators. The results indicated that high maternal sensitivity and cognitive stimulation predicted significant child language growth, but linguistic stimulation was associated with child language growth only in the context of high maternal sensitivity (readers are referred to Figure 1, panels B and C, from Cejas and Quittner in these Proceedings). Baseline maternal sensitivity is turning out to be a particularly important predictor variable in the CDaCI Study, being defined broadly as the parent's ability to perceive and respond to his or her child's behavioral signals (e.g., Barnard et al., 2015; Markman et al., 2011; Niparko et al., 2010; Tobey et al., 2013).

Cost Utility

As indicated in Figure 2, Quality of Life and Cost Utility are prominent areas of investigation in the CDaCI Study. We focus here on the societal benefits of receiving a CI early from a cost utility analysis that covers the first 6 years of the study (Semenov et al., 2013). Similar to the Niparko and colleagues (2010) study, the cost utility analyses was based on age receiving a CI (< 18 months, 18-36 months, and > 36 months). The analysis estimated medical/surgical/programming costs related to CIs, educational savings relative to not receiving a CI, and benefits with the CI. Benefit was indicated by quality-adjusted life years, or QALYs, gained over a projected lifetime. The youngest age-at-CI group gained the highest QUALYs (10.7 years) in comparison to the two later age-at-CI groups (9 and 8.4 years, respectively). When compared to children with severe to profound hearing loss who do not receive a CI, estimates of the life-time cost savings, including education, ranged from $31,252 for the earliest age-at-CI group to $6,680 for the latest age-at-CI group. The most significant outcome from the cost-utility analysis was the finding that CIs are one of the most cost-effective procedures in the U.S., derived from costs per QALY, irrespective of age at CI.

CONCLUSIONS

In summary, the strengths of the CDaCI study lie in its diverse national sample and longitudinal data collection on a number of age-appropriate measures. The study offers great potential for generalizable insights into the sources of variation in spoken communication and psychosocial functioning that affect long-term outcomes. Moreover, the CDaCI Study is expected to continue making important contributions as these children mature through their teenage years and possibly into early adulthood. The broad age range at enrollment (< 5 years) underscores the significant advantages of receiving a CI at an early age, which has been reported by other investigators (e.g., Dettman et al., 2016), and is certainly the current trend in clinical practice. However, receiving a CI at an early age is not the only factor to predict successful outcomes. Other contributing variables include auditory access to sound prior to receiving a CI, emphasis on listening and spoken language communication, and parent-child interactions (i.e., maternal sensitivity). Even with receiving a CI later in age, the CI is one of the most cost effective surgical procedures being performed in the United States. Despite the widespread positive effects of CIs in children, it is important to acknowledge that there are children with CIs who demonstrate pervasive delays in communication and other behavioral skills. This relatively small proportion of children warrants further investigation that will lead to individualized clinical and educational guidelines.

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We remember John K. Niparko, M.D. (founding CDaCI Principal Investigator, deceased), and Nancy E. Fink, MPH (original CDaCI Coordinator, deceased), for their dedication and significant contributions to the CDaCI Study.

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PEARLS: An Intervention to Improve Parent-Child Interactions and Communication

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ABSTRACT

Parents play a critical role in the overall development of infants and toddlers with hearing loss. Specifically, the quality of parent-child interactions, including maternal sensitivity (MS) and facilitative language techniques (FLTs), have been shown to positively affect children's spoken language. This article will report on a parent-focused intervention to improve parental sensitivity and communication (Parent-Child Early Approaches to Raising Language Skills – PEARLS). The effectiveness and feasibility of this intervention will also be discussed.

INTRODUCTION

Developmental studies have confirmed that language and communication are among the earliest and most important environmental factors that affect the development of cognition, affect, and social interaction (Bloom, 1998). Evidence indicates that typical development requires some level of effective communication, and lack of communicative ability has cascading consequences for cognitive, behavioral, and social development. Thus, for children with significant hearing losses, difficulties with communication present a substantial threat to optimal development, such as behavior problems, emotional difficulties, poor academic achievement, and difficulties with visual attention (Marschark, 1993; Quittner et al., 1994, 2004; Smith et al., 1998).

Ninety percent of children with sensorineural hearing losses (SNHL) are born to parents with typical hearing (National Institute of Child Health and Human Development, Early Child Care Research Network, 2000). Thus, an immediate "mismatch" between the hearing status of the child and parent (Gregory & Hindley, 1996; Quittner et al., 2004) presents a significant barrier to effective communication (Meadow-Orlans & Spencer, 1996). Parents often face unique challenges in providing appropriate stimulation and language input to their child with hearing loss. For children with severe to profound hearing loss, cochlear implant surgery facilitates the development of spoken language and these children are able to develop listening and spoken language skills that are comparable to their peers who have typical hearing. However, despite these positive results, there is significant variability in their language outcomes even after accounting for child age and length of implant use (Duchesne et al., 2009). Family variables, such as parent-child interactions and linguistic input, have been identified as key factors in the development of spoken language and communication abilities in children with hearing loss. This article will review the research related to the impact of parent-child interactions and linguistic input on the development of spoken language. In addition, preliminary results of a new evidenced-based parenting intervention, Parent-Child Early Approaches to Raising Language Skills (PEARLS), will be reported.

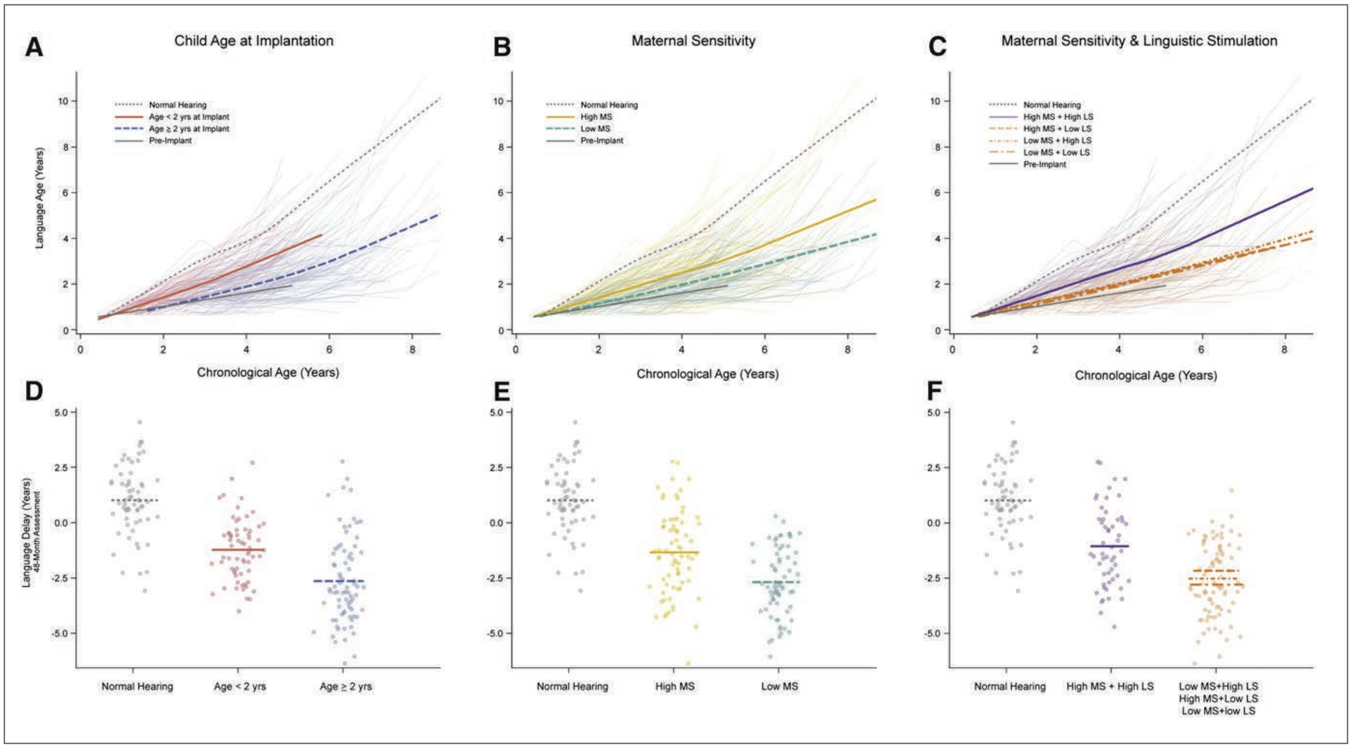
SUMMARY OF RESEARCH FINDINGS

Maternal Sensitivity

Early in development, parent-child interactions are a key source for: 1) emotional attachment, 2) development of cognitive and behavioral skills, and 3) communicative experiences (Bakeman & Adamson, 1984; Sroufe et al., 1999; Vygotsky, 1962). Observational studies have shown that, relative to mothers in hearing dyads, hearing mothers of children with hearing loss tend to be more controlling in their verbal and non-verbal interactions (Quittner et al., 2007), spend less time in coordinated joint attention with their child (Spencer & Waxman, 1995), and have greater difficulty responding to the child's emotional and behavioral cues (Swisher, 2000). The consequences of these disruptions include less secure attachment, difficulties sustaining attention and exerting behavioral control, and slower development of communicative competence (Bornstein, 2000; Bornstein et al., 1998; Lederberg & Prezbindowski, 2000). Quittner and colleagues (2007) have also found that general parental sensitivity, or 'attunement' (e.g., warmth, child-centered play, appropriate scaffolding), contributes to better overall outcomes for young children receiving a cochlear implant.

In a large national study of children using cochlear implants, the Childhood Development after Cochlear Implantation (CDaCI) study, we assessed maternal sensitivity (MS) in 20 minutes of videotaped parent-child interactions, including one

FIGURE 1. Language growth as predicted by maternal sensitivity and cognitive stimulation.



Notes: Compares language development, measured language age between **A**, age of implantation, **B**, high and low MS, and **C**, the interaction between MS and linguistic stimulation. Compares individuals with typical hearing and those who use cochlear implants, **D**, divided age received cochlear implant, **E**, divided by high and low MS, and **F**, divided by the interactions between MS and linguistic stimulation on language delay at 48-months after receiving cochlear implant.

Figure originally published in Quittner et al., 2013, Effects of maternal sensitivity and cognitive and linguistic stimulation on cochlear implant users' language development over four years. *Journal of Pediatrics*, *2*, 343–348.

unstructured (i.e., free play) and two structured (i.e., puzzle solving, art gallery) tasks. The CDaCI cohort is comprised of 188 children with severe-to-profound sensorineural hearing loss recruited from six implant centers across the US and 97 children with typical hearing from two preschools. Parent-child interactions were coded using codes well-established by the National Institute of Child Health and Development Early Childcare Study (National Institute of Child Health and Development, 2000). MS is a composite score (7-point scale) derived from ratings of sensitivity/responsibility, respect for child autonomy, positive regard, and hostility. This construct includes a quantification of observed warmth between the parent and child, the parent's ability to follow the child's lead and encourage independence, and the scaffolding of language and stimulation during play. Consistent with prior research, our study also revealed significant differences in MS between the group of children with cochlear implants and the group with typical hearing. Longitudinal analyses over four years indicated that MS was a significant predictor of growth of spoken language, even after controlling for early hearing experience, age at which the child received a cochlear implant, and key demographic variables (Quittner et al., 2013; see Figure 1). MS accounted for 11% of the variance in children's receptive and expressive language scores on standardized measures. Moreover, those parents who demonstrated higher MS in the context of greater linguistic stimulation had children who were 1.5 years more advanced in their language acquisition than parents with lower scores.

In summary, MS predicted changes in receptive and expressive language. Mothers who were more sensitive had children who performed better on standardized measures of language and communication (Quittner et al., 2007). The size of these effects were as large and similar as those found for age at which the child received a cochlear implant (before versus after age 2). This suggests that coaching parents in warmth, attunement, and positive regard may facilitate spoken language development.

Facilitative Language Techniques

Both quantitative linguistic input (e.g., number of different words, mean length of utterance) (Fewell & Deutscher, 2004; Hart & Risley, 1999) and qualitative linguistic elements (e.g., facilitative language techniques; Fey et al., 1999; Hulit & Howard, 1997) have also been associated with better language

TABLE 1. Description and example of facilitative language techniques.

FLT	Description	Example
Lower-level FLT		
Linguistic Mapping	Putting into words what the child says	Child hands mother a toy cat, mother says, "kitty."
Comment	Statement of phrase that signals a message has been received	Mother says, "yeah!" or "thank you."
Imitation	Parent repeats the child's utterance in whole or in part without evaluative remarks	Child says, "cup" and mother says, "yes cup."
Label	Parent labels an object, toy, or picture	Grandmother says, "There is a doggie."
Directive	Parent tells or directs the child to do something	Parent says, "Look!" or "You play with this cup."
Close-ended Question	Question or phrase for which the child can only respond with one word	Father ask child, "Is that your favorite?" or "Do you like that picture?"
Higher-level FLTs		
Parallel Talk	Provides linguistic labels that describe the parent and/or child's activities or aspects of the environment to which the mother and/or child is attending	Child is looking directly at the picture of a bee and parent says, "The bumble-bee is flying over the flowers."
Open-ended Questions	Question or phrase child can answer using more than one word	While looking at a picture, parent says, "What is happening in this picture?"
Expansion	Parent fills in the missing parts of the child's utterances while retaining the child's meaning	Child says, "baby cry" and the caregiver says, "The baby is crying."
Expatiation	Parent repeats the child's utterance and adds new information	While looking at the picture, the child says, "swim water" and mother says, "yes, we are going swimming in the beach. This summer we are going to the beach."
Recast	A form of expansion, involving a change in mood or voice; parent changes child's utterance into a question	Child says, "puppy gone" and the caregiver says, "Is the puppy gone?"

Table originally published in Cruz et al., 2013, Identification of effective strategies to promote oral language in deaf children with cochlear implants. *Child Development*, *84*, 543–559.

skills. Facilitative language techniques (FLTs) are strategies that parents or educators use to promote language in children who are deaf and hard of hearing or who have language delays. These techniques can be used with children from infancy through school-age and can be tailored to the child's age and language ability. FLTs can be divided into two categories: lower versus higher-level strategies (Table 1). Lower-level strategies consist of linguistic mapping, imitation, labeling, and closed-ended questions. Higher-level strategies include open-ended questions, expatiation, recast, and parallel talk. During the critical stages of language development, particular techniques are essential for developing more complex language. FLTs, such as open-ended questions, encourage conversation. In contrast, linguistic mapping and imitation are more didactic in nature and are more appropriate for children who are at the pre-linguistic and one-word level of language development (Girolmaetto et al., 1999; Yoder et al., 2001).

Few studies have investigated the impact of these specific language techniques on the spoken language development of children who are deaf and hard of hearing. DesJardin and Eisenberg (2007) evaluated the effect of FLTs on children using cochlear implants ages 2-7. In this study, parents' facilitative language techniques were coded during videotaped parent-child interactions (i.e., free play, storybook activities) and language was measured using the Reynell Developmental Language Scales. The use of higher-level language techniques, such as recast, were positively associated with children's receptive language abilities, while the use of open-ended questions was positively related to children's expressive language skills. In contrast, lower-level techniques, such as linguistic mapping, were negatively correlated with children's language abilities. This study also found that the mother's quantitative linguistic input, such as mean length of utterance (MLU), was associated with children's language skills.

A follow-up study conducted by the same researchers examined the relationship between early factors that may influence children's phonological awareness and reading skills over a three year period (DesJardin et al., 2009). Consistent with previous findings, results indicated that mothers' FLTs during 20 minutes of videotaped story book activities were associated with their children's later phonological awareness and reading abilities. Specifically, higher-level techniques, such as open-ended questions, were related to better phonological awareness. Open-ended questions were also positively associated to better

FIGURE 2. This figure shows the relation between number of different word types used by parents and improvements in receptive language raw scores over three years post-implantation.

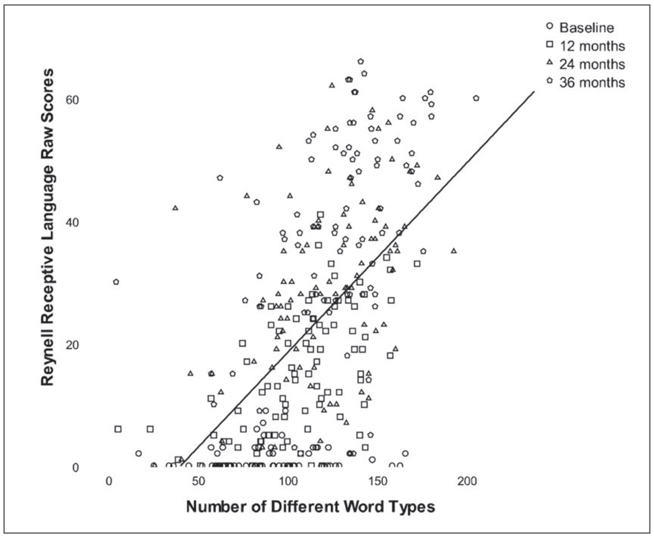


Figure originally published in Cruz et al., 2013, Identification of effective strategies to promote oral language in deaf children with cochlear implants. *Child Development*, *84*, 543–559

FIGURE 3. This figure shows the relation between higher-level facilitative language techniques (FLTs) and improvements in expressive language raw scores over three years of cochlear implant use.

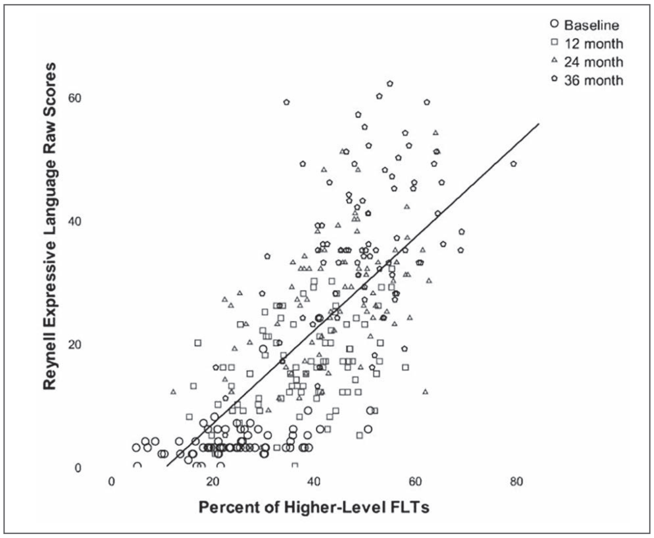


Figure originally published in Cruz et al., 2013, Identification of effective strategies to promote oral language in deaf children with cochlear implants. *Child Development*, *84*, 543–559

letter-word identification and passage comprehension. Recasting, a higher-level facilitative technique, was also related to better reading achievement (oral vocabulary and reading vocabulary) (DesJardin et al., 2009). In contrast, lower-level strategies, such as linguistic mapping, were negatively correlated with phonological awareness and reading achievement (letter word identification, reading vocabulary). Furthermore, mothers of children with higher language scores on the Reynell Developmental Language Scales or Oral Written Language Scales (OWLS) used more higher-level facilitative strategies than those with lower language scores (DesJardin et al., 2009).

The CDaCI study also showed that higher-level FLTs, such as parallel talk and open-ended questions, significantly predicted growth in expressive language over three years after receiving a cochlear implant (Cruz et al., 2013). In contrast, lower-level FLTs had no effect on either expressive or receptive language skills. Although lower-level FLTs, such as imitation and labeling, may enhance language learning in young children who are deaf and hard of hearing at the pre-linguistic stage of development (Warren et al., 2006), they did not appear to affect language learning in this sample of children using cochlear implants. Further, this study showed that the total number of different word types predicted greater improvement in receptive language (Figure 2). More importantly, a change in the number of word types over three years post-implantation predicted a faster rate of growth in expressive language (Figure 3). Overall, these results support prior work that has identified the influence of parent quantitative linguistic input on children's listening and spoken language development. These results have important clinical implications as they suggest that coaching parents to use more and higher level linguistic input leads to better spoken language outcomes for children who are deaf and hard of hearing.

PARENT-CHILD EARLY APPROACHES TO RAISING LANGUAGE SKILLS (PEARLS)

Based on the strong research evidence on the positive effects of parent-child interactions and parental linguistic input on children's development, we have developed an evidenced-based parenting intervention that coaches parents on increasing their sensitivity and use of higher-level language techniques. PEARLS is a 10-week program designed to be implemented during auditory-verbal therapy by a speech-language pathologist or certified Listening and Spoken Language Specialist. This manualized intervention is available in English and Spanish. It consists of session outlines, scripts for the therapist, homework assignments that focus on the skill taught that week, parent handouts, and copies of the assessment tools to monitor progress. During each session, therapists model a new FLT with the parent and child, training parents in the use of warmth, child autonomy, and reinforcing the child's progress with labeled praise and affection. Each session is divided into three 20-minute segments: 1) Free Play & Modeling of Sensitivity, 2) Training in Higher-Level FLTs, and 3) Auditory Training & AV Techniques, incorporating sensitive parenting. A homework assignment is assigned at the end of each session to practice the newly learned strategies.

This in vivo coaching model, which provides immediate feedback to parents, has been shown to be the most effective way to teach parents' new skills (Kaiser & Hancock, 2003; Thomas & Zimmer-Gembeck, 2007). Several studies, including meta-analyses, have reported parenting interventions as efficacious for improving child behavior by teaching parents strategies such as differential reinforcement. Interventions, such as Parent-Child Interaction Therapy (PCIT) and Positive Parenting Program (Triple P), have been derived from social and developmental theories and are considered evidenced-based interventions to improve the child's problem behaviors and communication skills (Thomas & Zimmer-Gembeck, 2007). The current PEARLS intervention uses similar techniques utilized in these interventions to improve parent sensitivity and use of language techniques. Specifically, a social learning theory perspective is employed to direct attention to the interactions between family members, rather than the child or parent independently.

We are currently developing manuscripts that discuss pilot data on the efficacy of the PEARLS intervention on improving sensitivity, parent-involvement and self-efficacy. Further data on feasibility and parent satisfaction with this program will also be discussed in future publications.

SUMMARY AND CONCLUSION

Research has highlighted the critical role parents' play in facilitating spoken language development in children with hearing loss and cochlear implants (Cruz et al., 2013; DesJardin, 2009; Sandall et al., 2005). In particular, the quality of parent-child interactions, specifically MS, has been shown to positively affect children's growth in spoken language (Quittner et al., 2013). In addition, studies have also identified the facilitative language techniques (FLTs) used by parents that are *most effective* in promoting language in young children with hearing loss (Cruz et al., 2013). Based on this research, Cejas and colleagues (2016) developed a parent intervention to target *parent-child interactions in the context of language learning*. Pediatric hearing loss programs should find ways to implement these brief parenting interventions that are cost-effective, ecologically valid, and have a substantial positive impact on the outcomes of children with hearing loss and their families (Goldfine et al., 2008; Kaminski et al., 2008).

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Supporting the Hearing Device Use of Infants and Toddlers Enrolled in Early Intervention

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ABSTRACT

For children with hearing loss who are learning spoken language, consistently wearing well-fit hearing devices is critical for optimal language development. However, device use during infancy and toddlerhood can be difficult to establish. In this paper, we describe the tools our lab has used to collect information about children's device use and family needs, as well as the findings from those studies. Additionally, we describe the evidence-based intervention strategies used in Ears On, the intervention we designed to increase toddlers' use of their hearing devices.

BACKGROUND

For children with hearing loss who are learning spoken language, research indicates that consistently wearing well-fit hearing devices supports optimal language development. For preschool-aged hearing aid users, recent findings indicate that the benefits of amplification are largest when hearing aids are fit appropriately and worn at least 10 hours per day (Tomblin et al., 2015). Similarly, research indicates that the amount of daily cochlear implant use is positively related to children's outcomes (Wang et al., 2011; Wie et al., 2007). Despite these well-documented benefits of consistent early auditory access, daily use of hearing aids and cochlear implants in infants and toddlers is often far from optimal (Marnane & Ching, 2015; Muñoz et al., 2016; Walker et al., 2013).

Although professionals have long known that hearing device use is difficult to establish in the first years of life, new technology is providing a better understanding of the scope of the problem. Most hearing devices now have a feature called data logging that can collect objective data on the duration of daily device use. Data logging in one recent study indicated that infants aged 6-24 months wore their hearing aids an average of 4.36 hours per day (Walker, McCreery, et al., 2015). It is worth noting that this is 2.43 hours per day less than the average use reported by parents. Poor use was also observed in a study that collected data logging information for young children with cochlear implants (age range 1-16 years), with infants and preschoolers averaging less than 5 hours per day, again contrasting with parents' reports of daily use, which were on average 1.81 hours per day greater across the entire age range examined (Walker, Van Voorst, et al., 2015). These findings fit with the results of other studies that indicate device use is typically poor in the first years of life and that parents usually overestimate how much children are wearing their devices (Muñoz et al., 2014). Part of the discrepancy between parent report and data logging may be that parents report average use for "good days," without averaging in days in which use was poor due to circumstances that do not affect their child's hearing device use on a daily basis. Although each circumstance may arise only occasionally, together they may have a cumulative impact on the child's overall device use that is substantial.

CHILDREN'S DEVICE USE AND FAMILIES' NEEDS: THE TOOLS WE USE IN OUR STUDIES AND WHAT WE HAVE LEARNED

Given that the first two to three years of life represent a critical period in children's development of speech and language skills, the negative effects of poor device use during this window are highly concerning (Bailey et al., 2001). In the research projects in our lab, we have utilized multiple tools to better understand how much infants and toddlers are using their devices and the barriers families experience that prevent establishing consistent device use. In this article, we describe a few of those tools, highlight several of the things we have learned from using them, and indicate how these tools might be used in the context of early intervention.

In most instances, the data in this section represent a subset of participants in a longitudinal study of 24 parent-child dyads in which the child had permanent, bilateral hearing loss and wore at least one hearing aid or cochlear implant. The infants and toddlers were recruited from the audiology, cochlear implant, and speech and language clinics at Boys Town National Research Hospital in Omaha, NE. At each visit with their child's audiologist during the course of the study, parents were asked to complete the questionnaires described in this article. Audiologists were asked to save the child's data logging information during the visit, which was later accessed by research staff. Audiological information was obtained from the child's medical records. The average age of the participants (15 male, 9 female) at entrance into the study was 15.63 months (*SD* = 10.1, range: 3.0-31.6). At the time of enrollment, 15 children wore bilateral hearing aids, 8 children used bilateral cochlear implants, and 1 child used a cochlear implant on one side and a hearing aid on the other. Two children with bilateral hearing aids received a cochlear implant during the course of the study. Eighteen children were diagnosed with sensorineural hearing loss, 4 with unspecified hearing loss type, and 2 with auditory neuropathy. The average age for confirmation of hearing loss was 3.3 months (*SD* = 3.3, range: 1.2-17.7) and children were first fit with hearing aids at an average age of 5.0 months (*SD* = 3.8, range: 1.9-19.6). Average age of initial activation of the first cochlear implant for the 11 children who utilized cochlear implants during the course of the study was 14.4 months (*SD* = 5.7, range: 8.3-25.2).

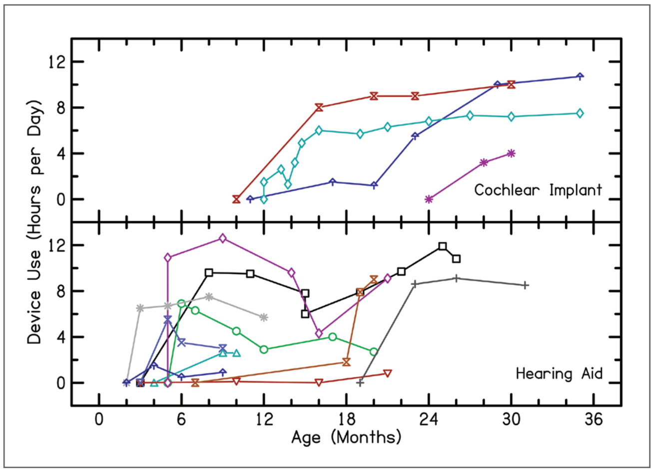
Data Logging

One of the tools we have utilized, both in this longitudinal study and in an intervention study, is data logging. Data logging is a feature present in most modern hearing aids and cochlear implants that can be accessed by the audiologist when the hearing device is connected to the device programming software. The objective information obtained through data logging allows the audiologist to see how the device is being used, including characteristics of the listening environments in which the device is being worn, which sound processing programs or features are being accessed in the device, and other usage details. Data logging also provides the average hours per day that the device is being used, which is the information we have utilized in our studies.

Data logging information was available for 19 children in the longitudinal study (5 children had no data logging information: 4 children wore cochlear implants with no data logging capabilities and 1 child's logging was not accessed during any clinical appointments). Their hearing device use mirrors that reported in other studies (Muñoz et al., 2014; Walker, McCreery, et al., 2015; Walker, Van Voorst, et al., 2015). The average data logging value at their most recent visit in the study was 4.7 hours for children with hearing aids (*SD* = 3.6 hours, range: 0.1-10.8; age in months: *M* = 14.0, *SD* = 8.0, range: 6-31), with 68.7% of the children using their devices less than 8 hours per day. Average use was higher for children with cochlear implants, at 7.1 hours (*SD* = 3.3 hours, range: 3.5-10.7; age in months: *M* = 29.0, *SD* = 8.2, range: 15-35). Three of the 5 children (60%) used their devices less than 8 hours per day.

We were especially interested in how hearing device use changed over time. In Figure 1, we have shown the device use trajectories for children who had at least two data logging values, with the latter being at least 6 months after fitting. The first data point for each child is a value of 0 and represents the age at which they were fit with their device. As can be seen in Figure 1, although overall there is a pattern of use increasing with age and device use experience, device use over time is quite variable for most children. This finding may represent the fact that as children age, the barriers to device use also change. For example, as children develop better fine motor skills, they may become more adept at removing their hearing aids, thus reducing use until parents can develop strategies to address this new barrier to consistent use. Device use may also change as childcare situations change, children become more mobile and thus at higher risk of losing devices, and so forth.

FIGURE 1. Longitudinal device use for 4 children with cochlear implants and 10 children with hearing aids.



This data highlights the need for frequent monitoring of device use, so that providers can determine when families need support in achieving or maintaining optimal levels of device use. For most early intervention providers, this will require developing relationships with the child's audiologist and the team frequently communicating with one another. This data also highlights the need for providers to frequently check in with parents regarding the barriers they are currently experiencing to device use, which we do using two questionnaires described here.

Early Hearing Device Use Questionnaire

One of the questionnaires we developed to monitor families' needs is the Early Hearing Device Use Questionnaire (EHDUQ). The questionnaire includes three sections. In the first section, parents are asked to indicate how often 15 issues have affected their child's device use in the past month. This section includes many items similar to those on the Parent Hearing Aid Management Inventory (PHAMI), a questionnaire developed by Muñoz and colleagues (2015). In the second section, parents are asked how much they agree with five statements, agreement with which could indicate parents need additional educational counseling or support. In the third section, parents are asked about how much their children wear their hearing devices in six different situations, which mirrors a task first utilized by Moeller and colleagues (2009) to help parents think about device use outside of what may be optimal environments.

We selected the items in this tool based on previous research regarding the barriers families experience to consistent device use. These include situation-specific barriers and barriers that are related to child or parent characteristics. Situation-specific barriers include the child being in a situation in which the challenges of retaining hearing devices lead to a high risk of device loss or safety concerns. For example, hearing aid use by children has been reported to be poorer in situations in which a parent is not closely supervising or in close proximity to the child, such as the car, outdoor play, or on public outings (Moeller et al., 2009). Parents also report more limited hearing aid use when the child is in the care of someone other than the primary caregiver (e.g., daycare providers). Use can also be negatively affected by child behavior or temperament, with some children being more resistant to putting or keeping on their devices and individual children's willingness to wear their devices changing with age and the achievement of motor and executive function milestones. Research indicates that parent characteristics can also serve to hinder or facilitate device use. For example, parental self-efficacy pertaining to managing their children's hearing technology is related to how much children wear their hearing aids (Muñoz et al., 2015). Similarly, parental beliefs in how much their children benefit from their devices is related to children's device use time (Mai et al., 2019).

Data are presented from the 62 questionnaires completed by 20 parents in the longitudinal study. The items included in the first section of the EHDUQ and data on the occurrence of the items are provided in Table 1. Although respondents indicated whether the barrier was experienced "never," "rarely," "sometimes," "often," or "always," data are sorted and summarized as the percent of parents who indicated the item had affected their child's device use at least rarely in the past month (responses of rarely, sometimes, often, or always). Although an occurrence that is rare may not affect use substantially, the existence of several barriers experienced, even rarely, is likely to affect use, thus we suggest at least bringing up each reported barrier with the parent, regardless of how frequently it was experienced. Indeed, although on average parents reported only one barrier that affected use "often" or "always," on average parents reported having experienced 6.5 barriers at least rarely. The item results indicate that device retention is a very common issue, with devices frequently falling off, children removing the devices, and families fearing loss of the devices. The third most common item, "Busy with other things happening in my home/family," highlights how much effort families have to put into ensuring their children wear their devices and how that naturally competes with the other things parents must focus on in their lives and their children's lives.

TABLE 1. Percent of questionnaires indicating each item had affected the child's device use in the past month.

Item	≥ rarely
1. Device(s) fall off of my child's head/ear	79.0%
2. My child takes the device(s) off	71.0%
3. Busy with other things happening in my home/family	64.5%
4. My child was sick	62.9%
5. Fear of losing or damaging the device(s) (For example, while outside, in activities around water, etc.)	61.3%
6. My child doesn't want to put the device(s) on	56.5%
7. Device(s) were beeping, squealing, or had feedback	41.9%
8. Ear infections or fluid in the ear	38.7%
9. Difficulty setting a routine with device use	37.1%
10. My child was with a caregiver who wasn't comfortable with the device(s)	35.5%
11. Device(s) were not working	35.5%
12. Fear of my child being harmed by the device(s) (For example, putting it in his/her mouth when I can't watch him/her, such as in the car, etc.)	29.0%
13. The device(s) were hurting my child and/or there were issues cochlear with the implant incision site	17.7%
14. Too expensive to pay for batteries, earmolds, device repair, etc.	14.5%
15. Situations where I don't want others to see the device(s)	4.8%

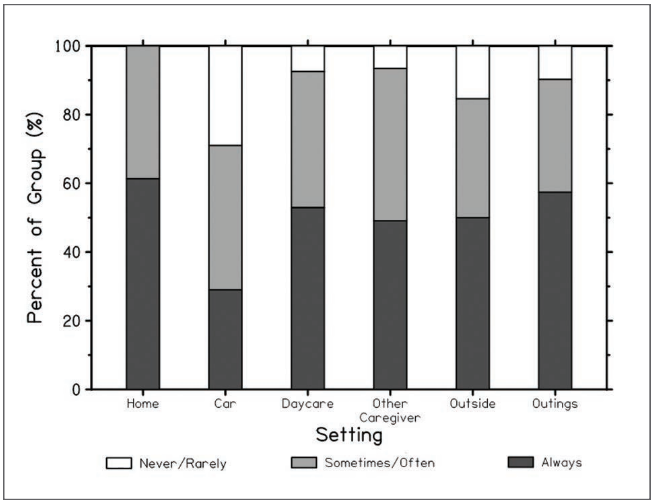
The findings from the second section of the EHDUQ are displayed in Table 2, with responses collapsed for "strongly disagree" and "disagree" as well as for "strongly agree" and "agree." The findings indicate that few parents agreed with the statements. However, the fact that 11% of respondents did not think the device helped their child may be concerning, as one could expect that parents who do not think the devices help their child are less likely to focus on optimizing device use. The finding that 16% of parents were unsure whether they agreed with not wanting their child to become dependent on the devices is another cause of concern.

In the third section of the EHDUQ, parents were asked to indicate how often their child wore their hearing device when awake and in the six settings. The findings from this section are displayed in Figure 2, with responses collapsed for "never" and "rarely" as well as for "sometimes" and "often." Use was highest for children at home and poorest for children in the car. Use was also relatively poor when children were playing outside or when cared for by other caregivers (family and friends) outside the home.

TABLE 2. Reported levels of agreement with five statements regarding device use.

Item	Disagree	Neither agree nor disagree	Agree
1. I don't think the device(s) help my child.	83.9%	4.8%	11.3%
2. Others tell me NOT to use the device(s).	93.5%	0.0%	6.5%
3. I don't want my child to become dependent on the device(s).	80.6%	16.1%	3.2%
4. I am not comfortable working with my child's device(s) (for example, changing batteries, making sure it is working).	95.2%	1.6%	3.2%
5. I am worried about how the device(s) look to others.	98.4%	1.6%	0.0%

FIGURE 2. Reported frequency of device use in six settings.



We suggest that early intervention professionals should ask parents to complete this questionnaire (or a similar questionnaire) at regular intervals or when alerted by the audiologist that data logging indicates device use has dropped, which would allow the professional to customize their intervention to the individual family's changing needs over time. This questionnaire allows the professional to identify when the family is experiencing new barriers to use, when parents hold a belief that may be negatively impacting their desire to optimize use, and in which settings the family needs more support to address barriers to use.

Scale of Parental Involvement and Self Efficacy - Revised (SPISE-R)

A third tool we have utilized in our research is a revised version of the Scale of Parental Involvement and Self Efficacy (SPISE). The SPISE was originally developed by Dr. Jean DesJardin (2003) and was revised by our lab, with input from Dr. DesJardin. The revised questionnaire (SPISE-R) includes items pertaining to parents' beliefs, knowledge, confidence, and actions relevant to supporting their child's hearing device use and language development. On the beliefs section, parents use a 7-point Likert scale to indicate how much they share eight beliefs. For each belief, a criterion exists for the score at which the belief may be concerning and thus warrant further educational counseling for the family. On the knowledge and confidence sections, parents use a 7-point Likert scale to indicate how much they know or how confident they are, respectively, about 5 items pertaining to hearing devices and 5 items pertaining to supporting their child's language development. On the action section, parents use a 7-point Likert scale to indicate how often they do seven items pertaining to device use, five items pertaining to supporting their child's language development, and three items pertaining to their child's intervention services. Scores for these three sections are each represented by the average score of the items in the respective section.

Parents in the longitudinal study filled out the SPISE-R when they initially enrolled in the study, as well as at 6-month intervals after enrollment. Responses from the most recent SPISE-R completed by 22 parents indicated that parents reported similar levels of knowledge, confidence, and actions pertaining to hearing devices as they did pertaining to supporting their child's language. Although on average, knowledge and confidence levels were high (all item averages were at least 4 or above, indicating on average parents had at least "some" knowledge regarding each item and felt "somewhat" confident with each item), there was high variability with many parents reporting limited knowledge and confidence with some items. Similarly, for the action items, only one item had an average score below 4 ("doing a daily check of my child's listening with the Ling 6-Sound test"), indicating that, on average, parents were completing all other actions at least "sometimes." Responses to the belief section, shown in Table 3, indicated that almost 25% or more of families expressed a level of agreement with four of the eight beliefs that met the criteria for "concerning" and thus may warrant further educational counseling.

Hearing Device Skills Test

One final tool we have utilized is a skills test for managing hearing devices. Although we have only used it in the context of a small intervention study, we mention it because of its potential for use in early intervention. We adapted the Practical Hearing Aids Skills Test-Revised (Doherty & Desjardins, 2012) to use with parents of children with hearing aids. We asked parents to do nine tasks: 1) remove the hearing aid from the child's ear, 2) open the battery door, 3) test and change the hearing aid battery, 4) clean the hearing aid, 5) perform a listening check, 6) put the

TABLE 3. Percent of parents with agreement level in the concerning range.

Item	%
1. No matter what we do as a family, my child's development will be delayed compared to children with typical hearing.	40
2. If I keep my home too quiet, my child won't learn to listen in noise.	36
3. If children are given the right supports, they can overcome the effects of hearing loss.	28
4. If people see my child wearing his/her hearing device(s), they will judge my child or family.	24
5. My child's hearing devices help him/her learn to communicate.	16
6. If children wear their hearing device(s) all the time, they will become overly dependent on them.	12
7. The quality of my child's service providers will have a big impact on how my child develops.	8
8. How my family talks to and interacts with my child will have a big impact on how my child develops.	4

hearing aid in the child's ear, 7) show or tell what to do when the hearing aid whistles, 8) perform a Ling 6-Sound test, and 9) show procedures and storage places for the child's hearing aids and related accessories. For each task, we recorded whether the parent performed the task with no difficulty, performed parts of the task with no difficulty and parts with some difficulty, performed the task with some difficulty, or was unable to perform the task. The three families in our intervention study were all able to demonstrate improvement in their scores after participation in the intervention. We think that use of such a tool in early intervention is critical for identifying when parents need additional hands-on coaching with device maintenance and troubleshooting. Improvements in parents' skills in these domains can reduce the amount of time children spend not wearing their devices because the device is broken due to an issue that could potentially have been handled at home, or reduce the amount of time children spend wearing a non-functioning or poorly-functioning device.

THE STRATEGIES WE USE IN OUR RESEARCH INTERVENTION FOR SUPPORTING PARENTS IN OPTIMIZING HEARING DEVICE USE

In our lab we recently developed and tested the effectiveness of an intervention designed to increase toddlers' use of their hearing devices. The intervention, called Ears On, is individualized to each family's needs, which are identified in an assessment using many of the tools described previously. After the assessment, each family participates in a workshop that seeks to ensure that parents: 1) understand their child's hearing loss, 2) recognize the impact that their child's hearing loss will have on speech and language development if consistent hearing device use is not established, 3) believe that hearing device use is the primary means of preventing language and other developmental delays associated with hearing loss, and 4) are empowered to help their child establish consistent device use.

After the workshop, parents participate in intervention sessions that are each individualized to target a barrier the family has experienced to consistent device use, such as a persisting belief that the child does not need the hearing devices, fear of the child being harmed by the hearing devices, or managing challenging child behaviors in relation to the hearing devices (e.g., taking the devices off and breaking them or resisting the hearing devices being put on by an adult). In the following sections, we share some of the strategies we think led to successful implementation of Ears On in our small effectiveness study.

Individualization Based on Use of the Tools

We found the use of the tools previously mentioned helpful in individualizing the intervention content to address the specific barriers families reported experiencing. This included using the tools to develop an understanding of parents' current beliefs, knowledge, and skills pertaining to their child's hearing devices, and identifying the barriers to consistent device use the parents were experiencing. The following provides a few examples of how barriers were addressed in intervention for individual families.

For one family, the primary barrier to use was the parents' belief that their child did not benefit from his hearing devices. This led us to share research results with the family, such as the finding from Tomblin et al. (2015) showing the different rates of language progress for children who do and do not wear their hearing aids at least 10 hours per day, and to present a simulation of what the child could hear with and without his hearing aids. With the family present, we also conducted assessments to illustrate what the child could and could not hear with and without his hearing devices, including how close the child needed to be to hear specific sounds and how the child responded when he heard the sounds. A useful tool for this type of assessment is the Early Listening Function assessment (Anderson, 2007). In this instance, the assessment validated the family's belief that their child was hearing, but also prompted them to evaluate how close he had to be to hear individual sounds. This lead to discussions about the implications for his ability to learn spoken language.

For another family, the primary barrier to use was concerns about the child's safety. This led us to focus on retention strategies, such as critter clips. In addition, we reviewed with the parents how the devices work, so they could understand the features that ensure the amplified sound was safe. Parents were also coached on troubleshooting of the device relevant to safety issues, including how to manage the batteries and how to identify issues with the device that could be safety concerns (e.g., cracked ear molds, broken tubing).

For families who reported that the child was resistant to putting or keeping on his or her devices, we worked with parents to gain insight into why a child may be resistant. We also worked with the family to modify their current routines in ways that made it easier to facilitate device use. For example, one family found that their child frequently removed his devices during unsupervised play following dinner, so after brainstorming with the interventionist the family changed their routine of having the child play independently while the parent did dishes after work. Instead, the parent chose to engage the child in supervised play and do the dishes after the child's bedtime. In another instance, a child would take the devices off after leaving child care. We helped the family understand that the child was likely removing the hearing aids to get the parent's attention and worked with the family on providing the child with positive attention and activities, to reduce the child's need to remove his hearing aids to get attention. We also discussed not giving the child negative attention when the child removed the hearing aids and instead calmly replacing the hearing aids and continuing with a positive activity (i.e., playing outside, reading books). The parent role-played these interactions with the interventionist and then received bug-in-the-ear coaching while playing and interacting with her child as he kept his hearing aids in place.

Data Logging

In our intervention study we collected data logging information from children's hearing aids twice a week and shared this information with families. This served as a valuable intervention tool because parents were able to develop a realistic understanding of how much their children were wearing their devices and then set and monitor their progress toward their device use goals. Parents reported finding this data very valuable. Unfortunately, this software is not available to most teachers, speech-language pathologists, or other early intervention providers at this time and instead can only be accessed by the child's audiologist. Therefore, we suggest that all early intervention providers form a collaborative relationship with the child's audiologist and work as a team with the parent to ensure everyone understands how much the child is wearing the devices and to identify the barriers the family needs help addressing.

Coaching Model

Our intervention utilized a coaching model, which we found worked well to build parents' self-efficacy, especially pertaining to managing the child's devices. For example, the interventionist modeled device maintenance and troubleshooting as well as how to do full listening checks and the Ling 6-Sound test. Parents not only observed the interventionist and listened as she narrated her activities, but they were also then encouraged to practice the same skills while receiving any needed support from the interventionist. This process allowed the interventionist to identify gaps in parents' knowledge and confidence. It also led to children spending less time wearing non-functioning devices. For example, we initially found that parents were often only checking to ensure that hearing aids were providing feedback when held. However, teaching parents to do listening checks and troubleshoot the devices allowed parents to consistently realize when the child's batteries were almost dead or that the sound quality from the device was poor due to dirt, moisture, or equipment malfunction. This process also helped us identify when parents weren't using a hearing device care item because they did not understand its importance (e.g., the hearing aid dehumidifier) or it had been lost. Another instance in which the coaching model proved especially powerful was with a parent who wanted to increase the amount her child wore his hearing aids in his educational setting. Instead of working directly with the educational staff, we supported the parent in developing, practicing, and sharing a presentation on her child's hearing aids with his educational team. This process was powerful in building the parent's self-efficacy.

SUMMARY

Families of infants and toddlers frequently have trouble establishing consistent device use. Early intervention providers should use available tools and work with parents and audiologists to determine which families need additional support to increase their child's use of his or her hearing devices. The supports should be individualized to address the barriers individual families are experiencing, which may include parents' beliefs, challenging child behaviors, and situation-specific barriers. All intervention strategies should seek to increase parental self-efficacy pertaining to supporting their child's device use.

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Family Environment Contributions to Children's Neurocognitive Development

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ABSTRACT

The variability in neurocognitive outcomes across children who are deaf and hard of hearing (DHH) who use cochlear implants and hearing aids is simultaneously a source of frustration for clinicians and caregivers, and an opportunity for scientists to investigate underlying sources of individual differences, particularly ones that might be altered through intervention. Biopsychosocial systems theories provide a framework for explaining risk of executive function outcomes in children who are DHH because they incorporate neurobiological, family environment and experiences, psychosocial influences, and cognitive factors to examine children's development. Factors that are nearest to the child and consistent (as opposed to transient) are likely to have the strongest influence on development. One such set of proximal factors is family environment and dynamics. The purpose of this article is to discuss how the family environment might contribute to resilience in otherwise known at-risk neurocognitive outcomes in children who are DHH and use hearing aids and cochlear implants. Targeting specific aspects of family functioning in future intervention work could support resilience in children who are DHH.

INTRODUCTION

Few, if any, aspects or systems involved in child development can be binned easily into those solely influenced by nature or nurture. Rather most, including the auditory system, are shaped by complicated, dynamic, and reciprocal processes between genetics, neurobiology, and experiences with the world and the people in it. Disruption to auditory development via any of these processes, especially early in development, can have important consequences for auditory system function (Kral, 2013). Reduced or absent auditory input early in development, particularly before the onset of language, directly influences the structure, function, and organization of auditory structures from the periphery through the auditory cortex (Sharma et al., 2002). Also affected are downstream abilities that depend directly on typical auditory system function, such as neurocognition (e.g., spoken language and executive function) (Kral, 2013; Kral et al., 2016). Additionally, reduced auditory experience also can indirectly influence downstream skills involving neurocognition via access to learning, dyadic communication interactions with caregivers, and adjustments to family interactions and environment. Many aspects of this indirect pathway, particularly the role that family dynamics and environment play, have been largely overlooked as contributing factors in the development of spoken language and executive function of children who are deaf and hard of hearing (DHH) (Holt et al., submitted). The purpose of this article is to discuss how the family environment might contribute to resilience in otherwise known at-risk neurocognitive outcomes in children who are DHH and use hearing aids (HAs) and cochlear implants (CIs).

NEUROCOGNITION IN CHILDREN WHO ARE DHH

There are two areas of neurocognitive development that are particularly vulnerable to reduced or lack of auditory input via both direct and indirect pathways: spoken language and executive function development. Spoken language of children who are DHH and receive CIs prior to approximately 18 months of age have receptive and expressive language growth trajectories similar to their peers with typical hearing (e.g., Niparko et al., 2010; Holt & Svirsky, 2008). However, they still lag behind their peers with typical hearing in absolute scores because they started behind when they received their CIs. Children receiving CIs at or after 2 to 3 years of age have language growth curves that get progressively shallower as the age they receive a CI increases (Niparko et al., 2010; Holt & Svirsky, 2008). On average, children with CIs have maintained a gap on standardized language measures of approximately 1 standard deviation below the mean for the last decade despite the most sophisticated signal processing available (Ching & Dillon, 2013; Fitzpatrick et al., 2011; Geers et al., 2009; Hayes et al., 2009; Holt & Svirsky, 2008; Niparko et al., 2010; Nittrouer, 2010).

For children with HAs, there are occasional reports of children with milder degrees of hearing loss closing the language gap (e.g., Fitzpatrick et al., 2011), but the majority report spoken language delays relative to their peers with typical hearing, albeit smaller than those seen in children with severe-to-profound hearing loss with CIs (Ching et al., 2013; Lederberg et al., 2013; Tomblin et al., 2015). It is particularly important for children who wear HAs to have consistent access to the full auditory signal for the development of spoken language (Ambrose et al., 2015; Tomblin et al., 2015). Whereas average spoken language scores give some indication of children's performance, they often can be misleading for predicting outcomes for any given child because scores vary from floor to ceiling across children in all of the large outcomes studies, even in children who receive early identification and intervention (e.g., Ching & Dillon, 2013; Niparko et al., 2010). Individual variability continues to be an insidious problem for clinicians and parents alike.

Executive functions are those neurocognitions that support active regulation and control of cognitive, emotional, and behavioral processes for generating and carrying out organized, goal-driven plans (Barkley, 2012). Executive function as an umbrella term consists of seven interrelated neurocognitive subdomains including: working memory, inhibition, controlled attention, shifting, concentration, emotional control, and active sustained mental effort (Barkley, 2012). Executive function develops via contributions from neurobiological maturation of the brain's prefrontal system, which has a protracted course of development through early adulthood (e.g., Ciccia et al. , 2009). Also important to the maturation of executive function are social contributions, particularly from proximal environmental sources around the developing child and adolescent (e.g., Bernier et al. , 2010). Access to speech and using spoken language provides opportunities to employ executive functions to attend to, concentrate on, and process temporally unfolding signals in working memory, and to use self-talk to regulate behavior and emotions (Alderson-Day & Fernyhough, 2015; Conway et al., 2009). Because of their different auditory and spoken language experiences, some children who are DHH (and primarily with CIs) consistently display three areas of elevated risk related to executive function development: 1) verbal working memory (the ability to actively regulate and update the contents in short-term memory while doing concurrent processing); 2) controlled fluency-speed (using controlled attention to maintain rapid and efficient processing of information); and 3) inhibitory control (resisting distraction and actively suppressing a pre-potent response to produce goal-directed behavior). A much higher percentage of children who are DHH than would be expected score in the clinically elevated range on these three executive function domains. In a normally distributed sample, only 16% should score in the clinically elevated range. However, it has been consistently found that anywhere from 25–40% of children with CIs score in the elevated range for working memory and inhibitory control problems (e.g., Holt et al., 2013; Kronenberger et al., 2013, 2014), and controlled fluency-speed difficulties (e.g., Kronenberger et al., 2013, 2014).

Furthermore, individuals who are DHH and use sign language have also shown similar risks in the same domains of working memory and inhibitory control (Hall et al., 2017). These findings have led some studies to conclude that there is a subpopulation of children who are DHH that are at "high risk for executive function difficulties" (Holt et al., 2013, p. 394). However, similar to the data on spoken language outcomes, the variability in executive function outcomes is enormous (e.g., Holt et al., 2013; Kronenberger et al., 2013, 2014; Pisoni et al., 2010). The variability in spoken language and executive function outcomes across children who are DHH is simultaneously a source of frustration for clinicians and caregivers, and an opportunity for researchers to investigate underlying sources of individual differences, particularly ones that might be malleable through intervention.

AN OPPORTUNITY: INDIVIDUAL DIFFERENCES

At present we have a very limited understanding of the factors that contribute to the development of children who are DHH, chiefly because most research until the last 5 years or so has focused primarily on device- and child-related factors. It is a widely-held view in most fields that child development is shaped by dynamic interactions between biology and environment (Bronfenbrenner, 1977). Biopsychosocial systems theories provide a framework for explaining risk of executive function outcomes in children who are DHH because they incorporate neurobiological, family environment and experiences, psychosocial influences, and cognition as factors in examining the trajectories of children's development. Biopsychosocial systems theories integrate well-accepted developmental concepts that have been characterized as Transactional (Sameroff & Chandler, 1975)—a series of bidirectional interactions between people; and Ecological (Bronfenbrenner, 1977)—a series of bidirectional interactions between people and their environment. Environmental factors vary in their ecological contexts and distances from the developing child (e.g., Belsky, 1981; Bronfenbrenner, 1977; Cicchetti & Lynch, 1993). Proximal factors and those that are stable (as opposed to transient) are likely to have the strongest influence on development (Lynch & Cicchetti, 1998). One such set of proximal factors is family environment and dynamics.

FAMILY ENVIRONMENT AND DYNAMICS: ASSOCIATIONS WITH INHIBITORY CONTROL IN CHILDREN WHO ARE DHH

Previous work from our research team has demonstrated that whereas family environments do not differ in gross ways between families of children who are DHH and families of children with typical hearing, specific aspects of family environment are associated with executive function outcomes in children who are DHH and use CIs and HAs (Holt et al., 2012, 2013, submitted). For the purpose of this article, we will focus on those related to inhibitory control. Families that placed an emphasis on organization and planning had children with fewer problems with inhibitory control (Holt et al., 2012), and families with low levels of conflict and high levels of support for one another (cohesiveness) had children with fewer inhibitory control problems (Holt et al., 2013). Recent data also suggest that whereas families of children who are DHH and those of children with typical hearing experience similar levels of overall stress, only in families of children who are DHH is stress related to language and executive function: even small increases in parental stress were related to more problems with these children's inhibitory control via poorer receptive language skills (Blank et al., submitted). Thus, family environment and dynamics independently contribute to the variability in inhibitory control.

Up to about 40% of the DHH population is at risk for inhibitory control difficulties in any given investigation. This also means that approximately 60% are not. Rather than asking the more common individual differences question, "what contributes to risk in this clinical population?," this article takes a resiliency approach and poses the question, "what aspects of the family environment are associated with positive executive function outcomes in DHH children?" Beginning to address this question is important because some aspects of family functioning are malleable and can be modified with family therapy and intervention (e.g., Bruce & Emshoff, 1992; Mills & Hansen, 1991). Targeting specific aspects of family functioning in future intervention work could support resilience in children who are DHH.

PRELIMINARY STUDY

Children's Characteristics

A sample of 72 children ages 3 to 8 years old, who were identified with sensorineural hearing loss and received intervention by 3.5 years of age, and their primary caregiver, who were participating in two studies with similar protocols, were identified to be included in this analysis. Thirty-four used HAs and 38 used CIs. None of the children had a severe intellectual or neurological disability. Their mean age was 6.47 years (*SD* = 1.4 years) and their mean age at hearing loss identification was 7.63 months (*SD* = 11.42 months). Children with HAs received their first HA on average at 14.86 months (*SD* = 14.5 months) and those with CIs received their first CI on average at 21.61 months of age (*SD* = 14.28 months). All of the children had a goal of using spoken language both at home and at school. Only one child (a CI user) used Total Communication; the remaining all used listening and spoken language communication.

Identifying Subgroups: Low- and High-Risk Groups for Inhibitory Control Difficulties. Children's parents completed the age-appropriate version of the Behavior Rating of Executive Function (Gioia et al., 2000, 2003, 2015), which is a parent-report questionnaire of everyday real-world executive function behaviors in children. Scores were converted to T-scores using age- and gender-specific norms, such that scores above 65 reflect clinically elevated executive function problems and those above 60 are considered elevated. Because of its susceptibility to hearing loss and links to language development (e.g., Holt et al., 2013; Kronenberger et al., 2013, 2014), as well as its strong ties academic readiness and achievement (Blair & Razza, 2007; Hughes & Ensor, 2007; Welsh et al., 2010), scores on the Inhibit subscale were used to identify children who were at elevated risk for problems with inhibitory control (> 60). This resulted in 21 children (29.2% of the sample) being retained and included in the "high-risk" group (mean Inhibit domain score = 71.0, *SD* = 6.5, range: 61-85). The 72 children's Inhibit domain scores were then sorted in ascending order, and those with the 21 lowest Inhibit domain scores were retained in what was labeled the "low-risk" group (mean Inhibit domain score = 41.2, *SD* = 3.5, range: 36-47).

Demographic information for the two subgroups of children are displayed in Table 1. There were no significant differences between the two subgroups for chronological age, age at identification of hearing loss, or family income bracket, p = .151 – .936 (Independent Samples t-tests). There also was not a significant difference in the representation of gender between the two groups, p = .217 (Pearson chi-square test). The representation of children with HAs versus CIs was different between the two groups (χ^2 (1) = 4.71, p = .03) with more HA

TABLE 1. Demographic information for the two sub-groups of children based on risk of inhibitory control problems.

Group	Mean (*SD*) Chronological Age (years)	Mean (*SD*) Age at ID (months)	Num. of HA users	Num. of CI users	Num. Female	Mean (*SD*) Income Bracket[a]
Low-Risk	6.4 (1.4)	8.8 (14.2)	15	6	8	8.2 (2.4)
High-Risk	6.4 (1.1)	7.8 (10.1)	8	13	12	7.0 (2.8)

Note. SD = Standard Deviation; ID = Identification; Num = Number; HA = Hearing Aid; CI = Cochlear Implant

[a] Parents indicated their annual income from the following income brackets: 1 = Under $5,000, 2= $5,000–$9,999, 3 = $10,000–$14,999, 4 = $15,000–$24,999, 5 = $25,000–$34,999, 6 = $35,000–$49,999, 7 = $50,000–$64,999, 8 = $65,000–$79,999, 9 = $80,000–$94,999, 10 =$95,000 and over.

users in the low-risk group and more CI users in the high-risk group. The single Total communicator was in the high-risk group. In other words, the groups were similar in audiometric and demographic characteristics outside of one factor, type of device use (and by extension, degree of hearing loss).

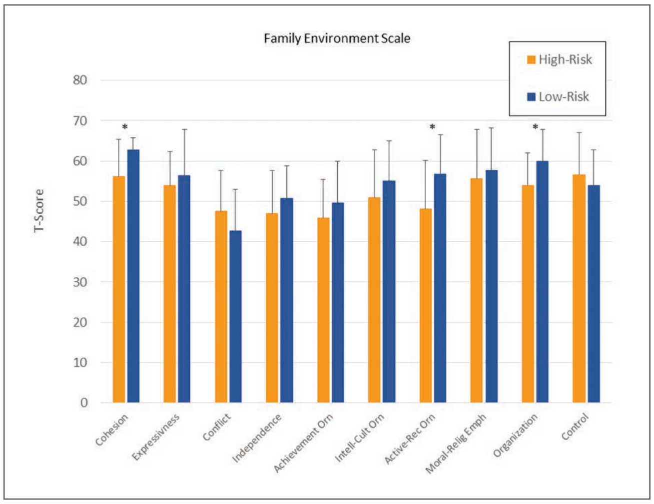
Measures and How They Were Administered

Children and a primary caregiver were evaluated in their homes as part of two larger studies on the role of family dynamics and environment on neurocognitive outcomes in children who are DHH and use sensory aids. Two clinical researchers with significant training in working with children who are DHH and their families visited the home: one worked with the primary caregiver and one worked with the child. Several methods of assessment were used including parental questionnaires, observation, and formal interview.

Executive Function. Primary caregivers completed the appropriate version of the Behavior Rating Inventory of Executive Function (BRIEF) based on their child's age: BRIEF (Gioia et al., 2000) or BRIEF-2 (Gioia et al., 2015) if their child was 6 years or older, or the BRIEF-Preschool (BRIEF-P; Gioia et al., 2003) if their child was 5 years or younger. The BRIEF-2 is an updated, slightly shorter version of the BRIEF. The BRIEF and BRIEF-2 assess the same eight domains of executive functions. Both scales were used because some of the children were assessed earlier than others and the BRIEF-2 was not yet available. The BRIEF contains 86 items, whereas the BRIEF-2 and BRIEF-P each contain 63 items. The only domain used for the analyses was Inhibit, which overlaps on all three versions used. The BRIEF/-P have been used with many clinical populations including children with ADHD, autism spectrum disorder, traumatic brain injury (TBI), and CIs (Beer et al., 2011; Gilotty et al., 2002; Holt et al., 2012, 2013; Jarratt et al., 2005; Mangeot et al., 2002; Pisoni et al., 2010).

Family Dynamics and Environment. Two measures were used to quantify dimensions of the family environment and family dynamics: the Family Environment Scale (FES; Moos & Moos, 2009) and the Home Observation Measurement of the Environment (HOME; Caldwell & Bradley, 2003). The FES is a 90-item, true/false parental questionnaire that assesses a broad set of family environment characteristics across three core dimensions: Family Relationship, Personal Growth, and System Maintenance. It has been used in previous studies of children with hearing loss and has been shown to account for variability in executive function outcomes (Holt et al., 2012, 2013). Raw scores are converted to normed T-scores. One family in the high-risk group did not complete all of the questionnaires included in the larger studies, including the FES. Thus, data are missing for one family on the FES from the high-risk group.

FIGURE 1. Mean FES subscale T-scores for each participant subgroup (+1 standard deviation). The group consisting of children with elevated inhibitory control scores are represented by orange bars and those with non-elevated scores by blue bars. Asterisks identify subscales in which scores significantly differed between the two groups, *p* < .05.



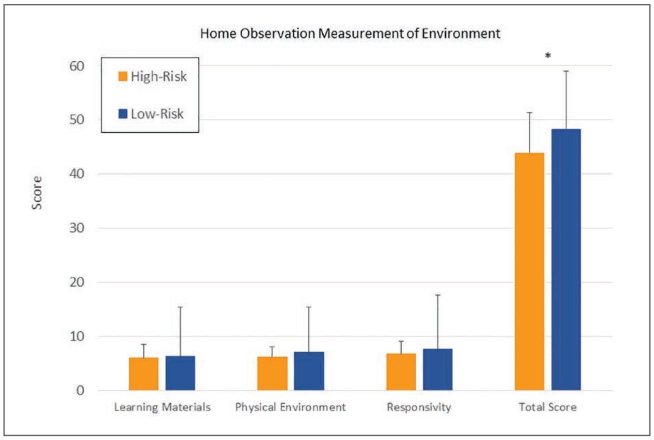
Note. Orn = Orientation, Intell-Cult = Intellectual-Cultural; Rec = Recreational; Relig = Religious; Emph = Emphasis.

Widely used in family systems research with children who have typical hearing, the HOME evaluates the quality and quantity of support and stimulation available to the child in their home via a semi-structured interview with the caregiver, paired with a guided observation of the home itself and interactions between the caregiver and the child inside the home. Like the BRIEF, the HOME has two versions based on the developmental age of the child. Only the Total Score and scales that overlap on the two versions were used in the analyses: Learning Materials, Physical Environment, and Parental Responsivity.

COMPARING FAMILY ENVIRONMENTS AND DYNAMICS: LOW- VS. HIGH-RISK GROUPS

Figure 1 displays the average T-scores for both child subgroups on each of the FES subscales. Overall, there was a trend for parents to rate their family environments differently depending on whether their child rated high or low on inhibitory control problems, with three scales significantly differentiating between the two groups: Cohesion, $t(39) = 3.078$, $p = .004$; Active-Recreational Orientation, $t(39) = 2.564$, $p = .014$; and Organization, $t(39) = 2.404$, $p = .021$. Relative to children at risk for inhibitory control problems, children who did not display such risk had families who provided high levels of support for one another, were involved in social and recreational activities with each other, and emphasized organization and structure in planning family activities and duties. Moreover, relative to children who are at risk for inhibitory control difficulties,

FIGURE 2. Mean HOME subscale and Total scores for each participant subgroup (+1 standard deviation). The group consisting of children with elevated inhibitory control scores are represented by orange bars and those with non-elevated scores by blue bars. Asterisk identifies where scores significantly differed between the two groups, *p* < .05.



children who did not show such risk came from more enriched home environments, where families provided a more stimulating and supportive environment (Total HOME Score, *t*(40) = 2.333, *p* = .025) (see Figure 2).

WHAT MIGHT THESE DIFFERENCES IN FAMILY ENVIRONMENT AND FAMILY DYNAMICS MEAN?

An important contribution to the development of executive function are the social and cultural influences that occur across many levels and distances from the child. Families are the most proximal and stable influences, and thus the most potent influences on children's social development (although peer and educational systems impact children's psychosocial and executive function development, as well) (Bernier et al., 2010). In early childhood, learning to regulate behavior can develop through modeling appropriate (or inappropriate) behavior of family members as well as practicing behavior and emotion regulation strategies and skills during interactions with family members. Families provide support, structure, and expectations (or lack thereof) through daily activities and interactions. Enriched homes, where families share more recreational activities and possess greater amounts of positive, supportive, and predictable experiences/environments, differentiate between children who are DHH who do not show risk for inhibitory control problems and those that do.

These findings are similar to our earlier work with a different type of analysis in which our research team found correlations between most of these same family environment and family dynamic constructs and children's inhibitory control outcomes (Holt et al., 2012, 2013, submitted). Positive, supportive, enriched, and predictable home environments appear to provide children who are DHH with learning opportunities for them to regulate and control their behavior. Inhibitory control is not only important for psychosocial development and academic success, it also is intertwined with language development. For example, inhibitory control is particularly important under degraded listening conditions when one must focus and attend carefully to the signal of interest and ignore interfering background noise (Stenback et al., 2016). Children who are DHH, more so than their peers with typical hearing, must rely heavily on inhibitory control when processing spoken language, even in quiet, because of their degraded speech perception and more poorly developed higher-level language skills (Kronenberger & Pisoni, 2018). Thus, children who are not at risk for inhibitory control problems can use this more effortful processing mechanism more effectively than children at risk for inhibitory control difficulties. It is important to point out that while subgroups here differed in their relative use of CIs vs. HAs (and thus, their language scores—note: language scores were not discussed in this brief article), previous results indicate that relations between executive function and family environment remain in children who are DHH even when language is controlled (Barker et al., 2009; Holt et al., 2013).

One limitation of this work is that there is no way to pin down directionality of any of these effects. In other words, having a child with significant inhibitory control difficulties probably influences the family unit, which could impact some of the family environment and family dynamic outcomes. As we are able to follow children and their families longitudinally, we will be able to better understand the bidirectional relations.

WHY MIGHT THIS BE USEFUL TO PARENTS, CAREGIVERS, AND CLINICIANS?

We are just beginning to to understand how family environment and family dynamics interact with important developmental outcomes in children who are DHH and use CIs and HAs. However, our research team has now replicated in several investigations that specific aspects of how families interact, organize themselves, and provide supportive and enriched learning opportunities influence neurocognitive outcomes in children who are DHH and use CIs and HAs. Previous investigations (Holt et al., 2012, 2013, submitted) have found that correlations between outcomes and family environment on some of the same factors that we found here differentiate between children who are at high vs. low risk for inhibitory control difficulties. What makes this work particularly exciting is that whereas hearing history is not something that can be altered once a child has been fit with HAs or receieved CIs, family environment and family dynamics are malleable with family-oriented programs (Hill & Balk 1987; Mills & Hansen 1991; Bruce & Emshoff 1992). If future longitudinal work determines that there indeed are aspects of family environment and family dynamics that protect children and support positive outcomes as suggested by these data, then these areas could be targeted for novel family-centered intervention.

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